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Application of Lu–Hf garnet dating to unravel the relationships between deformation, metamorphism and plutonism: An example from the Prince Rupert area, British Columbia

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ABSTRACT

The tectonic history of the Prince Rupert area is marked by profound crustal thickening from thrusting that produced inverted metamorphic field gradients and transpression in crustal-scale shear zones. Syn-tectonic garnet in the Prince Rupert area has Lu–Hf ages of 102.6 ± 3.7 Ma and 108.3 ± 4.1 Ma (2σ). Porphyroblast–matrix relationships in these samples, and samples from the same outcrops, indicate syn-tectonic garnet growth. These relationships imply that the garnet ages directly date the development of the metamorphic foliations. A third sample of migmatitic garnet amphibolite from the contact aureole of the 94–90 Ma Ecstall pluton had complex isotope systematics interpreted to indicate a garnet growth episode ~105 Ma, similar to the ages obtained from the other samples and a growth or equilibration event at ~94 Ma during pluton emplacement. The data show that the older Lu–Hf garnet ages date prograde metamorphism during foliation development and modification during pluton emplacement. The Ecstall pluton was emplaced 10 to 15 m.y. after regional metamorphism and thrust stacking in the Prince Rupert area.

In order to place our samples in a regional tectonic context we compare our results to patterns of regional deformation, metamorphism and plutonism throughout the North American Cordillera in the time period between 110 and 85 Ma. Contractional and transpressional deformation occurred throughout much of the North American Cordillera at this time, from southeastern Alaska to the Baja Peninsula in Mexico. Left-lateral transpression dominated the Canadian Cordillera, whereas, right-lateral transpression affected areas south of the Idaho–Salmon River suture zone, including the Sierra Nevada batholith. This reversal in kinematics in the northern and southern cordillera within coeval magmatic belts appears to be a first-order feature of the geology of the North American Cordillera during the Cretaceous.

1. Introduction

Several distinct scenarios have been proposed for the tectonics of the Coast Mountains; each makes unique predictions about the timing of deformation and plutonism. These hypotheses can be tested using precision geochronology, especially when focusing on syn-tectonic metamorphic minerals that provide the opportunity to directly constrain the timing of deformation, metamorphism, and plutonism. Garnet geochronology has previously been utilized as a method to date prograde metamorphism and thermal events, using both Sm–Nd (Burton and O'Nions, 1991; Getty et al., 1993; Stowell and Goldberg, 1997) and Lu–Hf isotopic systems (Scherer et al., 2000; Lapen et al., 2003; Anczkiewicz et al., 2004).

Here we present Lu–Hf garnet ages from three samples of schist and gneiss that occupy distinct positions within the western flank of the Coast Mountains in British Columbia near 54° N latitude. One sample was collected from between Ecstall pluton and the Grenville Channel shear zone, a second is from the strain gradient between Grenville Channel and Prince Rupert Harbour, and a third was collected from the aureole of the Ecstall Pluton within 500 m of the pluton at its most northeastern corner (Fig. 1). Our new data show that amphibolite facies metamorphism and deformation within the western metamorphic belt (WMB) predated emplacement of the Ecstall pluton. Complex Lu–Hf systematics from a garnet amphibolite near the margin of the Ecstall

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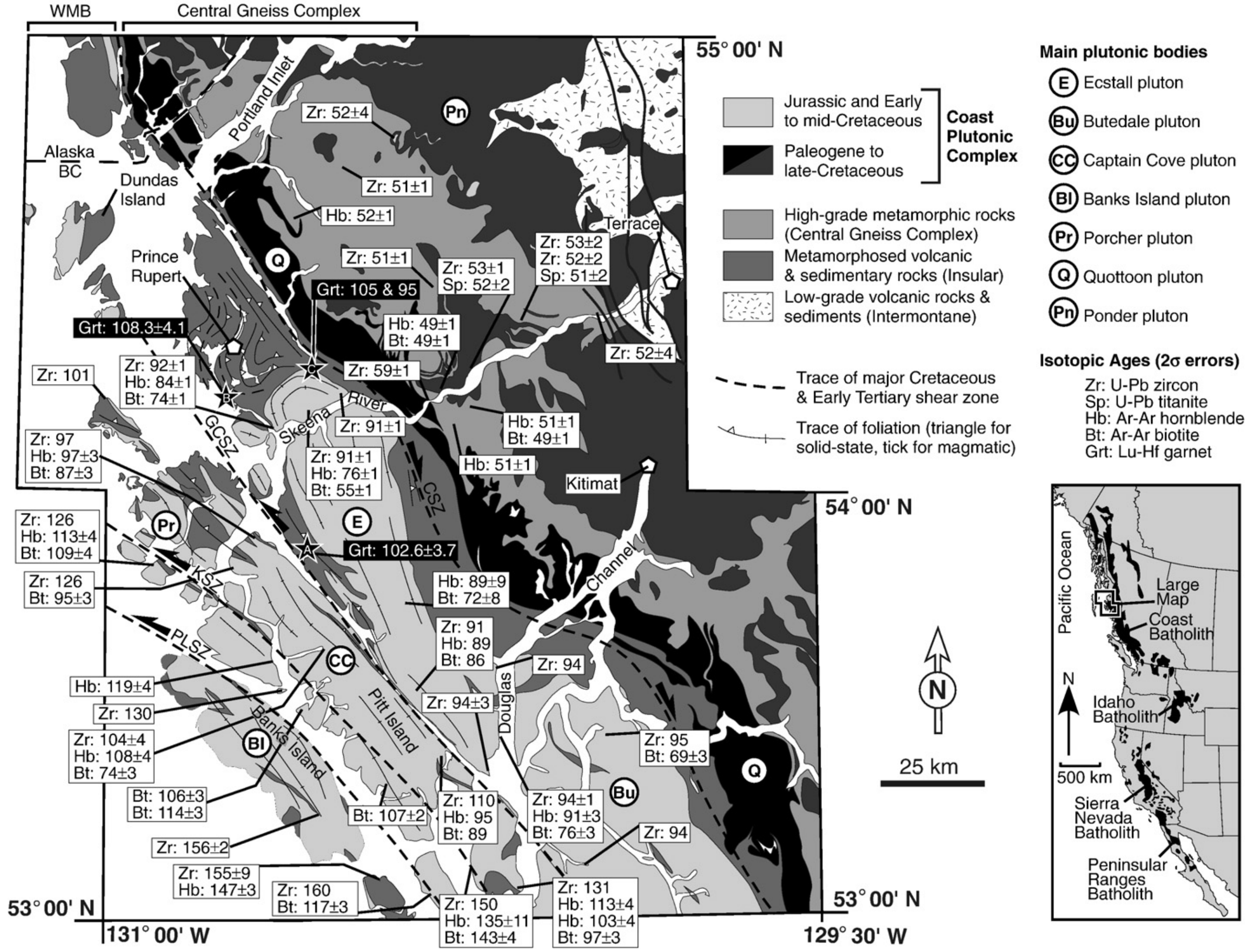

Fig. 1. Simplified geologic map of the Coast Mountains between 53° and 55° N latitude modified from Chardon et al., 1999. Foliations are representative of average trends for solid-state fabrics in metamorphic rocks and magmatic fabrics in plutonic bodies. CSZ — Coast shear zone, GCSZ — Grenville Channel shear zone, KSZ — Kitkatla shear zone, PLSZ — Principe Laredo shear zone. Sample locations from this study marked by stars with corresponding ages in black boxes: A is Kumealon Inlet (G-16), B is Ridley Island (98–114) and C is Minerva Lake (06B-57). Age on Banks Island is an average of five zircon ages ranging from 153 ± 1 to 157 ± 1 Ma. Inset map shows location of field area in the western North America cordillera with Cretaceous batholiths in black. Lithologies, foliations and structures compiled from: Roddick, 1970; Crawford and Hollister, 1982; Hutchinson, 1982; van der Heyden, 1989; Gareau, 1991; Cook and Crawford, 1994; Andronicos et al., 1999; Chardon et al., 1999; Rusmore et al., 2001; Mansfield, 2004; this study. Reported ages are 2σ error, compiled from: van der Heyden, 1989; Butler et al., 2002; Chardon, 2003; Andronicos et al., 2003; this study.

pluton document deformation in the WMB and contact metamorphism during pluton emplacement. These results better constrain the timing of structures in the Prince Rupert area, where K/Ar and Ar/Ar ages constrain the timing of cooling of the WMB from peak temperatures.

Our new ages are consistent with models that indicate deformation was synchronous with left-lateral transpression within the Canadian Cordillera (Chardon et al., 1999; Chardon, 2003), widespread deformation and magmatism within the Sierra Nevada (Busby-Spera and Saleeby, 1990; Ducea, 2001), and contraction and plutonism within the Idaho suture zone (McClelland et al., 2000; McClelland and Oldow, 2007; Giorgis et al., 2008). Plate-scale transpressional deformation is also observed throughout the North American Cordillera between 110 and 90 Ma (Hurlow, 1993; Monger et al., 1994; Chardon et al., 1999; Wyld and Wright, 2001; Umhoefer, 2003). Various plutonic bodies in the Coast Mountains of British Columbia were emplaced during this time period, but their exact relationship to transpressional structures has only been recognized within the last ten years (Chardon et al., 1999). Use of Lu–Hf dating of garnet enables us to directly date prograde metamorphism and development of deformational fabrics and better constrain the timing of transpressional deformation with respect to plutonism.

2. Regional geology

The western Canadian Cordillera and Coast Mountains of British Columbia were assembled through terrane accretion during the Jurassic and Cretaceous, but the source of those terranes and mechanics of emplacement are still widely debated. Two end-member models for the paleogeography of the Canadian Cordillera based on paleomagnetic and geological data have been put forward (Cowan et al., 1997). The first interprets shallow paleomagnetic inclinations to result from a variety of processes including tilting, shallowing of inclination during sediment compaction, and in situ deformation (e.g. Butler et al., 2006). Alternatively, analysis of paleomagnetic data for which tilting, inclination shallowing and in situ deformation can be evaluated has been interpreted to indicate large-scale translations of terranes from southern latitudes (Enkin, 2006). Further complicating the issue is the fact that plate reconstructions from this period are limited by either the